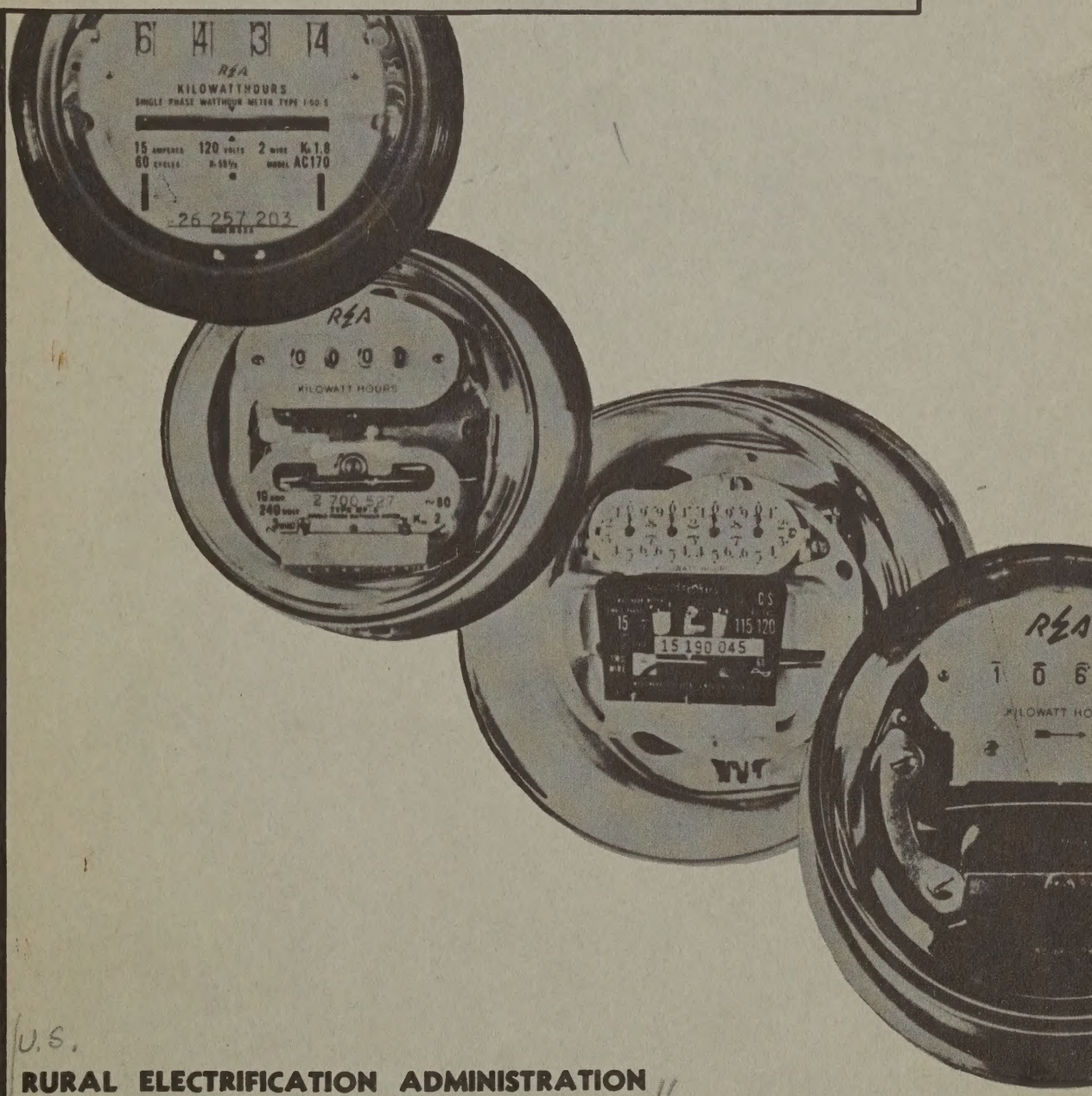
WATTHOUR METER MAINTENANCE



U.S.

RURAL ELECTRIFICATION ADMINISTRATION

U. S. DEPARTMENT OF AGRICULTURE

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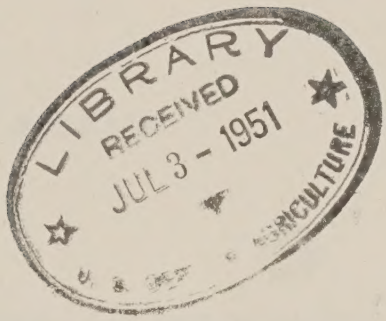

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PREFACE

This publication has been prepared to assist those metermen engaged in the servicing of single-phase watthour meters on rural power systems. It is intended to supplement presently available literature on the subject. When there is doubt as to the proper technique to use in servicing meters, the recommendations of the meter manufacturer should be followed.

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WATTHOUR METER MAINTENANCE

I. INTRODUCTION

The importance of proper care of watthour meters cannot be over-emphasized. The revenue of the REA cooperative is obtained through the registration of these devices. It is good business practice to see that these meters are accurate. If meters are registering fast, they create ill-will and penalize the members of the cooperative. If the meters are registering slow, as they generally do with increasing years in service without cleaning and recalibration, the cooperative loses revenue, shows reduced energy use, and appears to be operating with high line losses.

The watthour meter is basically a simple, rugged, dependable instrument that needs very little attention. Its reliability has been so remarkable that the American Standards Association has stated that testing of single-phase domestic meters below 12 kva rated capacity once every eight years is sufficient, providing local regulations do not require more frequent testing. However, if these meters are to maintain their accuracy over a span of eight years, they must have certain characteristics when initially installed:

1. The meters must be in correct calibration.

2. The bearings must be mechanically perfect.

3. All electrical connections must be secure.

4. The registers must be clean, show no evidence of high friction, and be correctly meshed with the disk driving gears.

5. All gaskets and seals must be in perfect condition.

6. The meters must be installed on the services correctly and operated under the load conditions for which they were designed.*

When all these factors have been given proper attention, the meters are capable of giving excellent service over a maximum period of eight years without further calibration.

Many REA cooperatives have meters that have been in continuous service longer than eight years. These meters should receive immediate attention. It is probable that some of the cost of servicing these meters can be defrayed by the increase in gross revenue created by the corrected registration of the renovated meters. The increase in good will of the consumers will more than justify the cost of the entire meter maintenance program. The mere fact that the consumers know that the cooperative is making every effort to see that the watthour meters are always in calibration aids considerably in the cooperative personnel-consumer relations.

The meter maintenance program should be carefully planned to permit the maximum utilization of cooperative personnel. It is not intended that tests be made on all the meters in one year and repeated each five to eight years thereafter. This creates an abnormal work load and is difficult to schedule properly. With proper planning the meters can be serviced at a fairly uniform rate. If the majority of the meters have been in service for several years and have not been

**A 15-ampere, 3-wire, 240-v meter is satisfactory for loads not exceeding 60 amperes. For applications of watthour meters consult the meter manufacturers or refer to the listing of watthour meters in the "List of Materials Acceptable for Use on REA-Financed Systems."*

tested, the maintenance schedule should be planned so that the older meters are serviced first. This should permit the meter maintenance to be a continual and gradual schedule with no periods of abnormal work loads. If the cooperative contracts for meter servicing, a compromise program must be worked out to allow the best utilization of the contractor's equipment and personnel.

It is suggested that meter record cards be marked with colored metal flags or by other suitable means. A different color or combination of colors can be used for each year of installation or year of last calibration. This method of marking makes it easy to select the meters that are to be serviced during each year.

II. METHODS OF SERVICING

When the problem of servicing watthour meters arises there is always the question of whether the meters should be serviced in the field, in the cooperative's meter shop, by a mobile field laboratory, by the meter manufacturers, or by contracting firms. There are some advantages and disadvantages to each method. They are outlined as follows:

A. Field Servicing With Portable Kits

Advantages:

1. Meters are not moved away from the consumer's location. Handling and transportation of meters are reduced.

2. Record cards on the meters remain the same. An additional entry is made to show the date of testing and calibration.

3. No interruption of normal billing procedure.

4. Consumer sees the meter being tested; good for public relations.

Disadvantages:

1. Facilities are generally not adequate for proper cleaning and repair of the meters. If testing is done only once in eight years, meters must be thoroughly cleaned and inspected.

2. Some meters will have to be returned to the shop anyway as they will need repairs beyond the scope of field servicing.

3. Servicing limited by weather conditions. Outside location of meters is not conducive to work during bad weather.

4. Meter tester distracted by children, curious consumers, and farm animals.

5. Generally not possible to make a 50% power factor test or high voltage test on the meter.

B. Shop Servicing

Advantages:

1. Ideal testing conditions. Testing can be done during bad weather when other activities are limited.

2. Complete repair facilities are at hand for complete repair and rebuilding of watthour meters. Adequate repair parts are available. A much better rebuilding and calibration job is possible.

3. The calibration equipment is more elaborate and complete. Testing efficiency and accuracy of the meterman is generally higher as he handles more meters per day than does the field serviceman.

4. Testing and rebuilding are done under better supervision.

Disadvantages:

1. May require change in meter records. If meters are picked up, tested, and returned to the same consumer within 48 hours, services can be "cut through" during that period and no record changes are necessary. This method of returning the same meter to the same consumer will increase transportation costs.

2. May interrupt the normal billing procedure.

3. Requires careful handling and transportation of meters. Meters must be transported with extreme care. Trucks should be equipped with special meter compartments or the meters must be individually packed for transportation. The meter compartment cardboard cartons used by manufacturers for shipping are adequate transportation cases if the cardboard interliners are in good condition. The cartons must be placed in the truck so they will not bounce from the vehicle floor or be struck by other objects.

4. May confuse consumers who are using self-billing methods. This is particularly true if meters with different register readings are substituted for the original meters.

C. Mobile Field Laboratory Servicing

Some power companies have combined the advantages of shop testing and field testing by adopting the mobile field laboratory. This consists of a special truck equipped with full shop testing equipment. The truck is moved about in the power company territory to service meters in a limited area about the truck location. Where the density of consumers is very high, such as in city and suburban areas, this method has proved very satisfactory. However, where the consumer density is low, which is characteristic of rural cooperative areas, the mobile field laboratory is not very satisfactory. The amount of equipment needed for such a laboratory is about the same as that needed in the meter shop and ties up a truck continuously. A mobile field laboratory will not eliminate the need for an adequately equipped meter shop. The additional fixed charges for the field laboratory and lost time on metermen and equipment generally result in excessively high costs for meter servicing.

D. Contracted Service

A few REA cooperatives have contracted for meter service from the meter manufacturers and engineering concerns that are properly equipped to repair and calibrate all types of meters. These contracts have generally proved to be very satisfactory. It must be emphasized that cost is not the only factor to consider in determining the method of servicing the watthour meters. The simplest and least expensive form of contract would be to hire someone with a field test kit to visit all the meters, adjust the light load adjustments to compensate for increased friction (probably with the meter cover off and in a stiff breeze) and report that all meters are now in correct calibration. THIS IS NOT A SATISFACTORY TYPE OF METER SERVICE CONTRACT. In the long run, this type of "meter service" will cost considerably more than having the work done correctly initially. A reputable meter service contractor will provide servicing equivalent to that performed in a completely equipped service shop at an average cost of about $2.00 per meter plus parts and transportation. Local conditions will determine the exact costs.

E. Choice of Servicing Method

It is the responsibility of the cooperative management to determine the most satisfactory method of doing the meter servicing. It must be emphasized that the cheapest first cost may not be the most satisfactory or the least expensive over a long period of time. Such factors as the number of meters to be serviced each year, availability of trained metermen, and availability of engineering or manufacturing concern for meter servicing must be taken into consideration when the decision is made on how the meter servicing is to be handled.

If the cooperative decides to do its own servicing, adequate testing facilities must be provided. Metermen must be well-trained and encouraged to attend the nearest special metermen's courses which are offered throughout the country each year. Some meter manufacturers offer special courses to REA metermen.

A well-trained meterman should continue to attend courses at regular intervals. This keeps him abreast of metering techniques, aware of new equipment developments, and familiar with practices used by other power systems.

Meter testing in rural areas is generally done only once in five to eight years. This means that the meters must be placed in perfect mechanical and electrical condition if they are to remain accurate over the time interval between servicings. Facilities are rarely adequate for such precision work in the field. Field testing with portable kits should be limited to complaint testing only.

If meters are to be maintained by the cooperative, they should be reconditioned and tested in a well equipped meter shop unless state or local regulations prohibit the removal of meters from the premises of consumers for testing. Shop testing may indicate higher first costs; however, the better workmanship and calibration accuracy of shop work will insure fewer meter replacements due to poor maintenance, accumulated dirt, and maladjustments.

III. THE METER SHOP

The meter shop should be dust-free and located in or near the cooperative headquarters building. The shop should consist of one or more rooms that provide adequate heating and lighting, easy access to the office records and the vehicle driveway or loading platforms. Spaces must be provided for meter storage racks, spare parts storage, meter repair work benches, and meter calibration bench.

In addition to 120/240-volt, single-phase power, the meter shop should have a source of three-phase, 240-volt power. The three-phase is desirable as 50% power factor tests should be made on the watthour meters. If three-phase power is not available, provision should be made to use a special phase-shift type phantom load for the 50% power factor tests.

The shop should also be equipped with a source of dry compressed air. This compressed air is to be used to aid in the cleaning of meters and for drying meter parts after they have been run through the proper cleaning and rinsing solutions. It is preferable to have the air compressor located in the vehicle repair shop or at some other distant point from the meter shop. This is to keep the mechanical vibration on the shop walls and calibration bench to a minimum.

IV. THE METER SHOP EQUIPMENT

The minimum test and repair equipment needed for a meter repair and calibration shop is as follows:

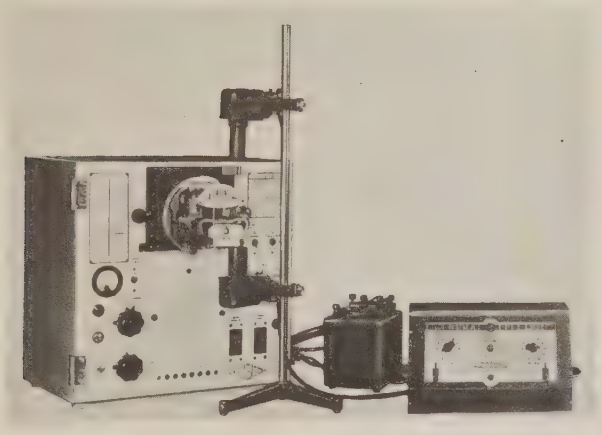
A. Portable Field Test Kit:

This kit includes the rotating standard, phantom load, and adapters for connection to socket- and bottom-connected meters. Practically all rural cooperatives have this unit on hand. It should be used only for infrequent portable field tests (complaint testing). The rotating standard should be calibrated against the shop rotating standard or check meters before each use.

B. Meter Test Board:

This instrument must include the artificial, or phantom, loads; provision for connecting the various types of watthour meters for testing, and provision for connecting the rotating standard watthour meter. This test board must also include a source of 1200 to 1500 volts a-c and suitable leakage indicators for insulation breakdown testing of meter coils. Good examples of this type of test board are the Tesco Portable Test Board, figure 1, manufactured by the Eastern Specialty Company and the Form HAPBL Portable Test Table, figure 2, manufactured by the States Company. These boards are priced from $450 to $500, complete with adapters and cords, but without rotating standard. The photoelectric counter shown in figure 1 may be desirable where sufficient

quantities of meters warrant its use. This counter can be used with either of the test boards.



Tesco Portable Test Board equipped with photoelectric counter.

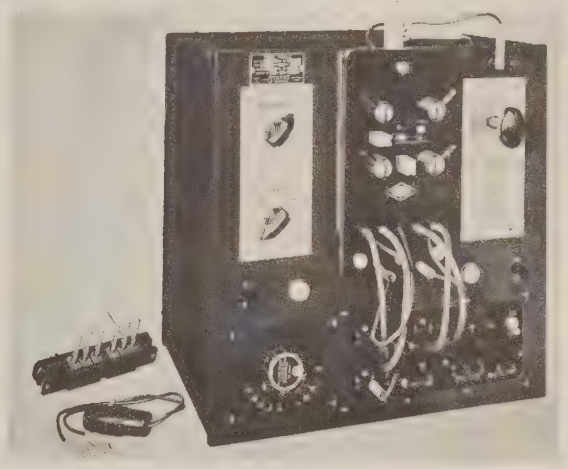
FIG 1

C. Rotating Standard Watthour Meter:

In addition to the rotating standard incorporated in the field test kit, there should be a standard that is used only for shop testing. This rotating standard should never leave the shop except for calibration. The rotating standard used in the field test kit generally has a maximum range of 15 or 25 amperes. The shop standard should have current ranges adequate for all ratings of meters that the cooperative expects to place in service. It is recommended that the shop standard be purchased with the 50-ampere range as it is likely to be needed in the future. Standard watthour meters with this range can be purchased from any of the watthour meter manufacturers and are priced at from $175 to $190.

D. Standard Check Meters:

As one is not certain how long the rotating standards will stay in calibration, some method must be devised that will provide adequate checks on the calibration accuracy. If the cooperative is near a large power company, university, or testing laboratory that has adequate laboratory facilities, arrangements may be made to have the cooperative's rotating standards calibrated. It is not recommended that the rotating standards be shipped to and from the calibration laboratory. The standards should be transported on the front seat cushions of an automobile after they have been calibrated.



States Company Form HAPBL Portable Tes Table.

FIG 2

If it is not possible to obtain frequent calibration checks from nearby facilities, adequate calibration can be maintained by installing three standard check meters. These check meters are established as follows: Three new watthour meters, all identical, should be mounted above the meter calibration bench. The registers are to be removed from the check meters. On meters having the worm wheel separate from the register, the gear should be disengaged from the meter disk. The current and potential coil terminal connections to the socket blades are to be rearranged so that the potential and current circuits are completely separated. A good arrangement is to leave the potential leads connected to the top blades. Reconnect the current leads to the bottom blades. On three-wire meters the current coils are to be connected in series so that the current through each of the current coils will produce forward torque. If the above terminal arrangements are used, the top jaws of the three check meter sockets are to be connected in parallel and energized with the proper voltage. The voltage connection should be from the same outlet box that feeds

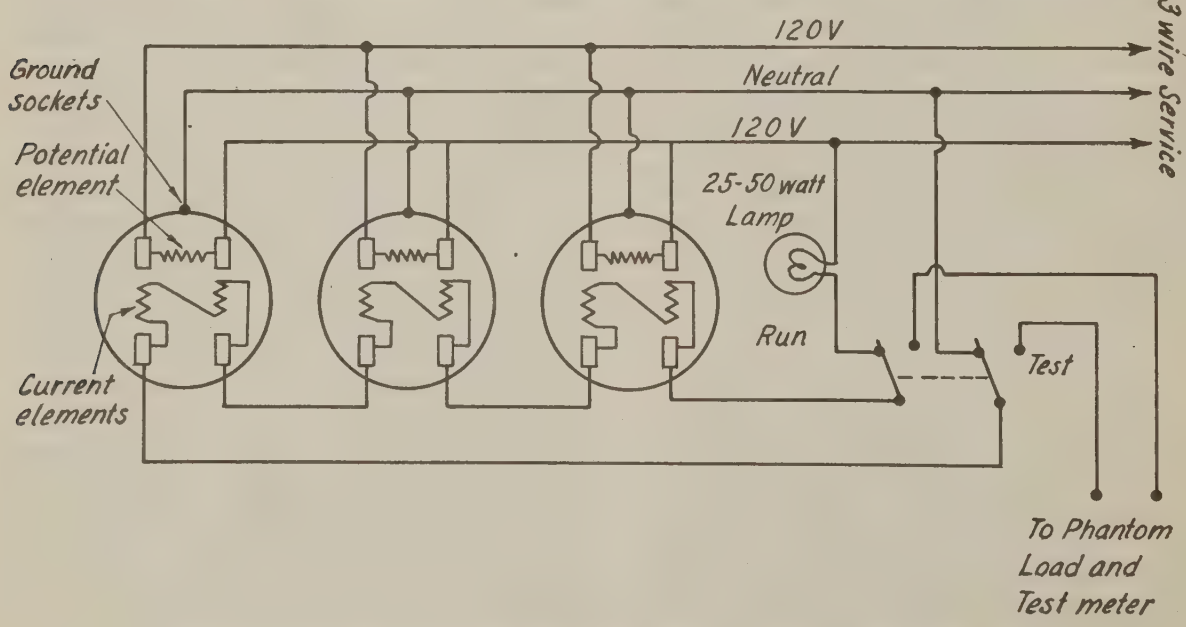
the meter test board. This is to insure that the voltage on the three check meters is the same as used on the rotating standard. THE POTENTIAL CIRCUITS OF THE CHECK WATTHOUR METERS ARE TO STAY ENERGIZED AT ALL TIMES. The current coils of the three check meters are to be connected in series. The connections are to be brought to a convenient place on the meter calibration bench. This is to allow placing the current circuit in series with the phantom load and the rotating standard.

It is desirable to provide a double-throw switch in the current circuit so the check meter current circuit can be switched over to the supply line and the meters left under a constant lamp load of 25 to 50 watts. A suggested wiring diagram for check meters, using 3-wire, 240-volt meters is shown in figure 3. The constantly energized potential and current circuits of the meters aid in keeping them at constant temperature and permits closer calibration accuracy. The slow rotation caused by the lamp load reduces the tendency for the bearings to become gummed as a result of being idle for long periods of time.

calibrated as accurately as possible with a newly calibrated rotating standard. Each calibration run must be made with the glass covers on the meters. The three meters are now secondary standards for comparison with the rotating standards.

It is obvious why three meters are needed. If only two were used and one of them drifted off calibration, one would not know which of the two meters was accurate. If three are used, one can drift off calibration while the probability is that the other two will remain together, thus revealing which meter is in error.

A calibration check between the check meters and the shop rotating standard should be made at least once each 30 days. As the field test kit rotating standard will have infrequent use it should be checked against the shop standard or the check meters each time it leaves the shop. A calibration record card must be maintained on each rotating standard. The rotating standard indicated readings must be adjusted on the basis of the calibration record. For



Wiring Diagram for Check Meters, using 3-wire, 240-v meters.

FIG 3

After the check meters have been energized for about two hours, they are

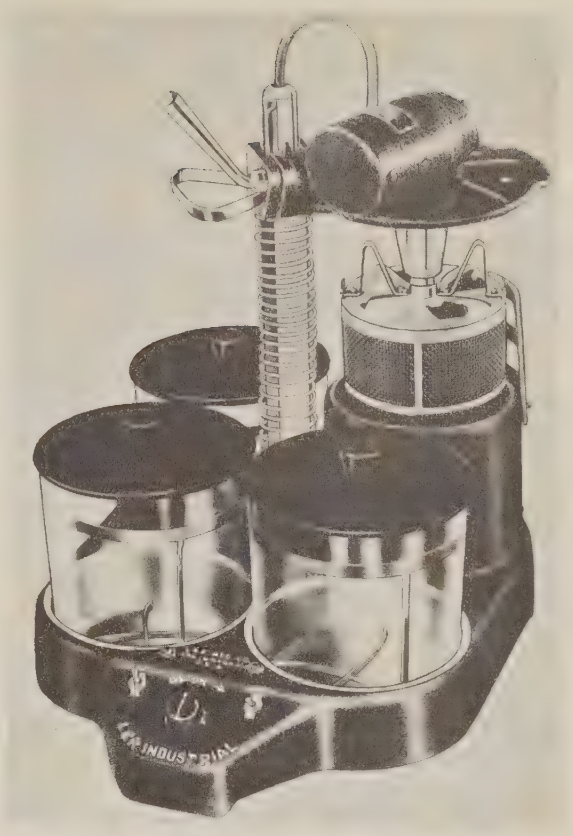
example: If the rotating standard, over a period of months, has shown a slow

drift to the point that it is 0.4% fast, this error must be taken into consideration when the rotating standard is used to calibrate watthour meters. If the proper record cards are maintained on the rotating standards and the errors considered when service meters are calibrated, it is not necessary to send the rotating standards away for calibration as long as they show consistent errors. However, it is suggested that the standards be sent to the proper laboratory for recalibration when the error is more than 0.5% from the last calibration as shown by the three check meters.

E. Meter Parts Cleaning Equipment:

Some method of cleaning the meter registers and parts must be provided. The common cleaning agent, carbon tetrachloride, is not a satisfactory cleaner for these parts. Certain gums and residues are left on the surfaces that interfere with the long-time accuracy of the meter. There are cleaning solutions on the market that have been used successfully for meter cleaning. In general, these consist of separate cleaning and rinsing solutions. Adequate cleaning can be done by using these solutions in shop-constructed equipment. However, some labor savings can be realized by using the special machine that has been made for this purpose. The machine, the L&R Cleaning Machine, figure 4, can be purchased for approximately $260, while the cleaning and rinsing solutions are about $2.00 per gallon. Both are available from the Eastern Specialty Company. As the quantities of the cleaning and rinsing solutions needed for routine meter maintenance is very small, the solution cost per meter is negligible. These solutions are used throughout the power industry and are recommended for REA cooperative use.

The shop-constructed cleaning equipment can consist of a series of glass battery jars of the type normally used with home d-c lighting systems. Covers can be made for these jars to keep the fluids covered except when in use. Provisions



L & R Cleaning Machine.

FIG 4

should be made for two rinses. This eliminates practically all traces of the washing solution. Drying should be by dry compressed air or low heat oven.

A satisfactory meter cleaning solution can be made locally. The following solution and cleaning procedure has been in use by several power companies for many years with satisfactory results. The process is inexpensive, requires a minimum of equipment, and leaves the parts free of gums and residues.

Cleaning Solution

1 gallon of stronger ammonia------28% solution
1 gallon of denatured alcohol
1 lb. oleic acid
1/2 lb. borax (20-mule-team is satisfactory)

Dissolve the borax separately in warm water and add to the other ingredients. ADD SUFFICIENT WATER TO MAKE FIVE GALLONS.

Rinsing Solution

Stoddard Solvent. This is generally sold under the equivalent of one of the following trade names:

Stanosol or Varsol (Standard Oil Company)
Stoddard Solvent (Gulf Oil Company)
Shell Mineral Spirits (Shell Oil Company)

Cleaning Procedure

The above cleaning solution must be handled with protective rubber gloves. The solution is strong enough to remove gums, smoke stains, and other discolorations from meter registers. There may be a tendency for the cleaning solution to soften the painted numerals and printing on some of the older types of meter registers. For this reason, all registers must first be dipped in the rinsing solution (Stoddard Solvent) before being brought into contact with the washing solution. The solvent retards the action of the cleaner sufficiently to eliminate its tendency to soften the painted surfaces. The washing time should be limited to a maximum of one minute. This gives sufficient time for the operator to scrub the surfaces of the register with a toothbrush or other suitable brush. The washing operation should be followed with two rinses. Drying should be done with the dry compressed air. If there is any doubt about the desirability of cleaning certain meter parts, the recommendations of the manufacturer should be followed.

F. Meter Jewel Inspection:

In the process of servicing watthour meters, the metermen find it difficult to be absolutely sure that the meter jewels are in perfect condition. The cost of providing the small cooperative with proper jewel inspection equipment is generally too high for the service obtained from such equipment. The basic inspection and jewel polishing equipment with approximate prices is as follows:

Jewel polisher, motor-driven	$ 25
Binocular microscope.....	260
Light source and condenser..	50
Light reflector prism.....	25

The total cost of inspection equipment thus becomes approximately $360.

An alternative to the need for the above equipment is to have the jewels inspected and cleaned by a meter or jewel manufacturer. Some of the manufacturers have established meter jewel inspection service. This service is such that the cooperative can ship to the manufacturer a package of jewels (for example, 500 jewels that have been removed from meters); the manufacturer cleans and inspects the jewels. The bad jewels are removed from the group and replaced by new ones. The package of cleaned and inspected jewels is returned to the cooperative. Some manufacturers also return the bad jewels, properly labeled, to the cooperative. The total cost varies with the manufacturer; some manufacturers charge only for the new jewels, others have a nominal charge for the inspection and cleaning. This service offers some assurance to the small cooperative that good jewels are used in all the meters. If this type of service is used, it is suggested that, when a meter comes in for cleaning and calibration, the jewels be removed. The inspected and cleaned jewels and a new pivot or ball are installed in the meter after it has been given the normal reconditioning treatment. A supply of new jewels must be purchased for the first group of replacements. Those jewels removed from the meters can then be sent to the manufacturer for the inspection and replacement service. The process is repeated until all meters have been serviced.

G. Meter Repair Tools:

The meter repair bench should be adequately equipped with tools for servicing the watthour meters. Complete tool kits are available from the meter and meter test equipment manufacturers. Certain tools are essential to good meter repair. As bearing balls and pivots must not be touched with the fingers, a ball-dropping device and pivot wrench must be provided. Special jewel bearing wrenches, socket wrenches of the nut-

driver type, and magnet-cleaning brushes aid the meterman in the rapid and accurate repair of meters. It is estimated that an outlay of $25.00 will provide adequate tools for servicing any one make of watthour meter.

H. Shop Instruments:

Ohmmeter

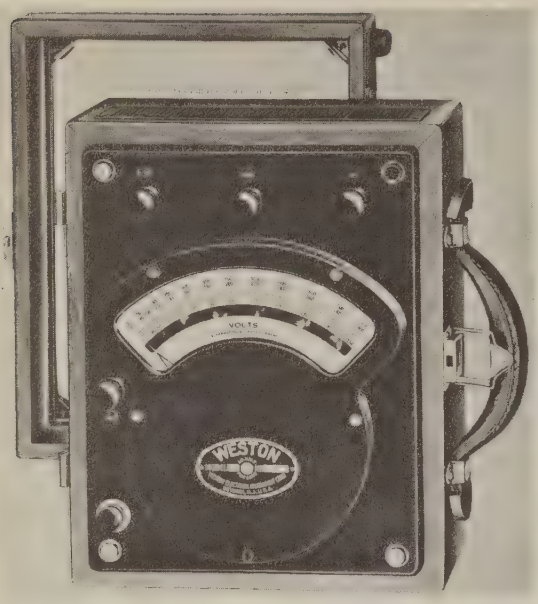
It is desirable to have a multi-range ohmmeter in the service shop. The ohmmeter is useful in detecting open potential and current coils. The high-voltage test used in conjunction with the meter test board will reveal if the insulation level is too low. The commercially available ohmmeters are of little value in detecting shorted current coils. The normal resistance of these coils is so low that a shorted turn cannot be detected accurately. The behavior of the watthour meter during its tests is more reliable in detecting troubles of this type. The ohmmeter will show changes from the normal resistance of potential coils, thus revealing if the winding has been damaged. It is suggested that an ohmmeter of the hand-cranked generator or vibrator type be used. These instruments should have a test potential of at least 100 volts, preferably 500 volts. Satisfactory examples of these instruments are as follows: Catalog No. 7672-R (0-10,000 ohms/20 megohms), 100-volt generator, manufactured by the J. G. Biddle Company, priced at about $233; Model 201 (0-2000-ohm/200-megohm), 0-150/300/600-volt a-c, 500-volt vibrator supply, manufactured by the Associated Research, Incorporated, priced at about $125.

Voltmeter

Every rural cooperative meter shop needs a precision voltmeter with at least plus or minus 1/4% accuracy. This instrument is to be the standard for all voltage calibration. This instrument can also be used to check all the field portable instruments, calibrate recording meters, and as a standard for the adjustment of voltage regulators. This instrument should not be subjected to everyday field use. It cannot be expected to maintain its very high degree of accuracy if it is transported in the rear of pick-up trucks or the trunks of automobiles. It should be treated as a precision instrument. If it has to be transported to field locations for special tests, it should be carried on the front seat cushions of passenger vehicles. There are several satisfactory instruments available for this purpose. Some of these are as follows: Type P-3, 0-150/300 volts a-c, Catalog No. 126199 manufactured by the General Electric Co.; Model 341, 0-150/300 volts a-c, manufactured by the Weston Electrical Instrument Corporation. Each is priced at about $160. These instruments are illustrated in figures 5 and 6.

Portable Standard Voltmeter, General Electric Company Type P-3.

FIG 5.

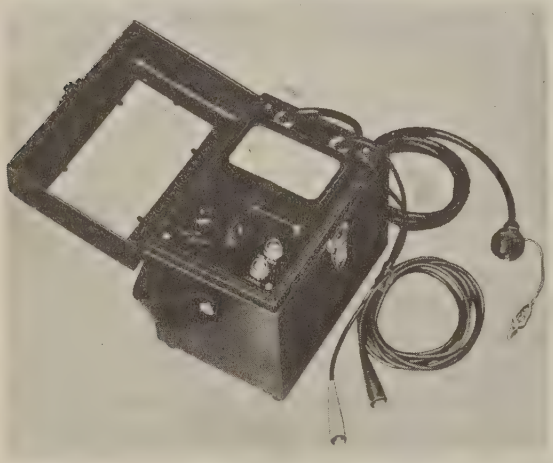


Portable Standard Voltmeter, Weston Electrical Instrument Corp. Model 341.

FIG 6

High Voltage Tester:

Some of the rural electric cooperatives have constructed meter test boards from portable field test kits. In general these conversions may prove satisfactory. However, some method of providing a high-voltage test must be incorporated. It is recommended that a 1500-volt a-c test be made on each watthour meter immediately after the "as found" tests are performed. Those cooperatives that have made the test bench conversion from the field test kit can obtain adequate high-voltage tests by using an instrument equivalent to the Hypot, Jr., Model 412, manufactured by the Associated Research, Incorporated. This instrument has a variable 60-cycle output voltage to a maximum of 1500 volts. It is equipped with glow lamps to show excessive current leakage and shorts. This device is illustrated in figure 7 and is priced at about $135. This instrument is not necessary if a meter test board with high-voltage test provision is used.



High-Voltage Tester. Associated Research Company, Model 412.

FIG 7

V. METER TESTING PROCEDURE

As all watthour meters, both new and reconditioned, must be calibrated before they are ready for installation, a definite procedure should be established for handling them. In general, new meters will require little repair, needing only a thorough inspection and adjustment to the proper degree of accuracy. The following procedures should prove adequate for both new and reconditioned meters:

A. Testing of New Meters:

When new meters are unpacked, brush them off or blow them off with compressed air to remove all packing material, bits of cardboard, dust, etc. This will aid in keeping foreign matter out of the meter interior when the glass cover is removed. The meter serial numbers should then be properly recorded on the cooperative meter record cards. If the cooperative uses its own system of numbers, see that the number blanks are properly stamped and recorded against the manufacturer's serial numbers. The meters are then given the following inspections:

1. Check all connections, both electrical and mechanical.

2. Check for foreign matter on the magnet pole faces.

3. Check the disk for proper align-

ment with the magnet pole gap. Readjust if necessary.

4. Check the register for proper meshing with the disk gear. There should be positive engagement but sufficient play to eliminate binding. Approximately 1/2 to 2/3 full mesh is generally satisfactory.

5. Check the register ratio to be sure it is proper for the rating and disk constant (K_h) of the meter.

6. Inspect cover gasket for proper seating to meter base.

7. Make all normal calibration tests, record "as found" data, and adjust to required accuracy.

8. Replace cover of meter and seal.

9. Record on the meter record card the exact calibration of the meter as the "as left" setting.

10. Store the meter in the proper racks or meter cartons for future installation.

B. Testing and Reconditioning of Old Meters:

When the meter is brought in from the consumer's location it should be tested, reconditioned, and retested on the following procedure:

1. "As found" tests and recording of "as found" test results on meter record forms. Do not write information on the back of meters. Attach a card with the service information to the meter.

2. Apply high-voltage test.

3. Remove meter from test bench, recondition as indicated by service card, and return to test bench for final calibration and adjustment.

4. Repeat full inspection for new meters as outlined above.

The details of the various steps above are generally done in the following manner:

1. "As Found" Tests and Recording on Meter Forms

The meter is first checked carefully to determine that the meter serial number and the cooperative serial number check with the meter record forms. This check is performed before the meter cover seal is broken. The register ratio and register reading should be checked at this time. This is important as it eliminates the possibility of switching meter registers or changing meter register settings. If the meter accuracy as determined by subsequent tests shows cause for consumer billing adjustment, the adjustment will apply to the correct consumer.

The meter is now connected to the meter test board and complete accuracy tests performed. The light-load (10% of rated current), full-load (100% of rated current), 50% power-factor, and the creep tests are made with the glass cover still on the meter. If local regulations require a 50% load test, it should also be made. The results are entered on the meter record and service forms. It is important that a complete summary of the "as found" tests be available to the repairman. The types of inaccuracies of the meter are indicative of the repairs needed.

2. High-Voltage Tests

After the "as found" tests have been completed and the data entered on the proper meter record forms, the meter is subjected to the high-voltage breakdown tests. This consists of placing all elements, both current and potential, at a 60-cycle voltage of from 1200 to 1500 volts to the meter frame. The same potential is applied between the current elements of three-wire meters. BE SURE THAT ALL COIL TERMINALS

ARE ISOLATED FROM GROUND OR METER FRAME DURING THIS TEST. THE POTENTIAL LINK MUST BE OPEN DURING THE THREE-WIRE CURRENT ELEMENT TEST. The high-voltage test as incorporated in some meter test boards automatically isolates the proper coils from ground when the high voltage test is applied.

The high-voltage test is needed to show which meter coils, if any, have reduced insulation. This reduction in insulation can be caused by previous lightning surges through the meter, extremely high currents through the meter resulting in overheated operation, or slow deterioration of insulation over a long period of years. It is important to find out which of the coils have reduced insulation so they can be eliminated from future service. Meters of low insulation level are a constant source of trouble. If they can be eliminated in the repair shop, it will save many field trips replacing meters that fail in service. If the coils fail during the high-voltage test, the information is also entered on the meter record forms for the repairman.

3. Reconditioning of Meters

After the "as found" and high voltage tests, the meter is sent to the repair bench. The repairman makes a study of the "as found" test record to get an idea of what special attention to give the meter. The cover is removed and placed aside for cleaning. The register ratio and meter constant are again checked to be sure the correct register was initially installed on the meter. The register is removed and if required, is given a complete cleaning. It is not recommended that registers be reset to zero. To accomplish this, some types of registers require a run-back of most of the gearing. The chances of damaging the gearing over-shadow any advantage of having the register set to zero. However, if the register is designed for rapid resetting by declutching or demeshing the gearing, there is little damage likely and resetting to zero is permissible.

The bearings and disk are removed. If bearing inspection is done locally, the jewel bearings are thoroughly cleaned and wiped out with soft wood or corn pith. If jewels are inspected by a jewel manufacturer as previously outlined, the jewels are placed in the "used jewel" containers subject to shipment. If there is any question of condition or if new jewels are installed, all lower pivots, or ball bearings, are replaced. In no case should the pivots or ball bearings be handled with the fingers. Special wrenches are used to seat the pivots and special ball-dropping devices are used to drop the balls in the bearing cups when reassembled. If bearing lubrication is recommended by the meter manufacturer, use only lubricant and quantities specified by the manufacturer.

The disk is inspected for mechanical damage such as bent shaft, worn or gummed worm gear, and warped disk. If the disk is damaged, it should be replaced. If the worm gear is gummed, or the disk is dirty, it should be cleaned in the solutions and dried. Additional cleaning of the worm gear can be done with a stiff brush. Smoked or stained spots on the disk is evidence that there has been an electrical flashover in the meter. All meters with this indication should have the elements carefully tested and inspected for insulation damage. The disk should be carefully inspected for metal particles adhering to the disk surface. If these cannot be readily removed, the disk should be replaced.

The top bearing assembly is inspected for mechanical alignment. If the guide pin is bent, it should be replaced. If it is in good mechanical condition, it is cleaned in the solutions and dried.

The magnetic structure and base of the meter is inspected for loose connections, evidence of electrical flashover, and damage to the meter blades. The entire

structure is cleaned by means of compressed air or by giving it a thorough brushing. Particular attention is to be given the magnet pole gaps. The gaps must be free of all foreign matter. A special brush will assist in this phase of the cleaning.

The meter base is inspected to see that the insulators on the base or socket blades are in good condition. The base vent holes are inspected, on those meters so equipped, to see that they are open. On those meters using screened vent covers, the screens are inspected to see that they are not damaged or clogged. If the meter base plate shows evidence of rusting, it should be stripped of all parts, thoroughly cleaned and refinished by spraying or brush painting with a good quality enamel or lacquer. A good example of enamel for this purpose is Sherwin Williams Company gray enamel, REX-H-68AN4 compounded of three resins, melamine, urea and alkyd. This type enamel must be compounded specifically for air or oven dry.

The meter glass is cleaned and the gasket replaced. On those meters having gaskets cemented to the cover, the new gaskets should also be cemented in place with a cement recommended by the meter manufacturer. On those meters using a ring type gasket inserted in the base groove, cementing the gasket to the meter base is necessary. All glass covers should be sealed before the meter is placed in the ready-for-service racks or replaced in the meter cartons.

C. Interpretation of Test Results: A study of the performance of the meter on the "as found" tests are indicative of the things to investigate when the meter is opened for repairs. The following summary may be of assistance in determining the cause of meter inaccuracies:

Test Result	Probable Cause And Suggested Remedy
1. Meter fast -- about same percent on light and full loads.	Weakened magnets, generally due to lightning surges. Also may have been inaccurately adjusted when last tested. Change magnets if necessary.
2. Meter fast -- greatest error at light load. May also be creeping.	Previously compensated for high friction by adjustment of light load. Cause has been removed. Inspect bearings, register, and worm gear.
3. Meter fast--on 50% power factor lagging.	Short in potential coil. Change if necessary. Open lag coil in some meters will cause this. Check with the meter manufacturer to determine effect of open lag coil.
4. Meter slow -- at light load and full load.	May have been inaccurately adjusted when last tested. Foreign matter in magnet pole gaps causing disk to drag. Ground or short-circuit in potential coil.
5. Meter slow -- greatest error at light load.	Indicates high friction. Remove bearings and register, clean or replace. Inspect worm gear, magnet gaps, check mesh clearances. May also have been inaccurately adjusted when last tested.

Test Result	Probable Cause And Suggested Remedy
6. Meter slow--slow on both light and full load but much slower on 50% lag.	Short circuit in current coil. Change if necessary. Check with manufacturer to determine effect of open lag coil.
7. Meter creeps--but is correct on both light-and full-load.	Shows evidence that excessive friction has been compensated by means of the light load adjustment. Remove register and bearings. Clean or replace. Inspect worm gear, magnet pole gaps. Also inspect to see that the potential coil has not been connected to the load side terminals.
8. Meter creeps--tests O.K. in laboratory but creeps when installed on consumer's service.	Indicates that the test potential used in the laboratory is lower than that at the consumer's location, resulting in overcompensation when installed on the service. Check voltage at consumer's location; if it cannot be readjusted, adjust the meter for the higher voltage. May also be subjected to excessive vibration or stray fields from other circuits near the meter.
9. Meter creeps -- either forward or backward, and is either fast or slow on light load.	Short circuit in the current electro-magnet. Change if necessary.
10. Meter dead--fails to rotate under any load condition.	Open potential coil or link. Foreign matter has disk locked. Disk bent. Locked register. Replace necessary parts.
11. Meter disk rotates but fails to register.	Disk worm failing to mesh with register. Dogs at rear of register out of mesh. Defective register. Adjust or replace.

VI FINAL ADJUSTMENT OF WATTHOUR METERS

Each power company has its own accuracy requirements for watthour meter calibration. These are based upon the regulations of the utilities commissions under which the power company is serving, or upon the desires of the company management. In any case, the accuracy requirements of the utilities commissions are equaled or exceeded by the operating companies.

The cooperative should use the accuracy requirements of the local state utility commission as its minimum calibration requirements when adjusting watthour meters. It is recommended that meter testers adjust all watthour meters to within a minimum of 99.5% of true registration on both full-load and light-load tests at unity power factor.

It is often desirable to determine the effective registration (generally for billing adjustment purposes) of a meter that is found out of calibration on the "as found" tests. As the individual rural consumer load is seldom constant throughout the entire day or month, the full-load rating

of the meter cannot be used for billing adjustment. On the other hand, the light load rating (10% of the full-load rating) is not correct for determination of the registration error. A study of rural loads indicates that the meter operates near the full-load rating not more than 1/5 of the day. The balance of the time (4/5 of the day) the meter operates in the vicinity of the light-load rating. Based on this assumption, the effective registration of the meter is as follows:

$$\%ER = \frac{4(LL\ R) + 1(FL\ R)}{5}$$

%ER = percent effective registration
LL R = light load registration (as found)
FL R = full load registration (as found)

Example

"As found" tests indicate the meter is as follows:

Full load registration = 105.5%
Light load registration = 92.0%

Percent effective registration =

$$\frac{4(92.0) + 1(105.5)}{5}$$

Percent effective registration = $94.\dot{7}$

References

Electrical Metermen's Handbook, Sixth Edition, 1950

Repair and Testing of Watthour Meters, Nov. 1944, Duncan Electric Company

Manual of Watthour Meters, GET-1840, General Electric Company

Meter Operating Problems of a Public Utility, J. C. Langdell, A.I.E.E. paper 50-126, March 1950

Manufacturers of Meter Test Equipment

The following partial list of manufacturers of meter test equipment has been prepared for information purposes, with the understanding that no discrimination is intended and no guarantee of reliability implied:

Meter Test Boards

The Eastern Specialty Company
3617 - 19 North 8th Street
Philadelphia 40, Pennsylvania

The Electrical Facilities, Inc.
164 So. Central Street
Los Angeles, California

The States Company
Hartford, Connecticut

Artificial and Phantom Loads

The Eastern Specialty Company
3617 - 19 North 8th Street
Philadelphia 40, Pennsylvania

The States Company
Hartford, Connecticut

Rotating Standards

The Duncan Electric Company
Lafayette, Indiana

The General Electric Company
Schenectady, New York

The Sangamo Electric Company
Springfield, Illinois

The Westinghouse Electric Corporation
95 Orange Street
Newark 1, New Jersey

Photoelectric Counters

The General Electric Company
Schenectady, New York

Instrument Cleaning Machine and Cleaning Solutions

The L. & R. Manufacturing Company
Newark, New Jersey

Sold through:

The Eastern Specialty Company
3617 - 19 North 8th Street
Philadelphia 40, Pennsylvania

Meter Repair and Service Tools

The Duncan Electric Company
Lafayette, Indiana

The Eastern Specialty Company
3617 - 19 North 8th Street
Philadelphia 40, Pennsylvania

The General Electric Company
Schenectady, New York

The Sangamo Electric Company
Springfield, Illinois

The States Company
Hartford, Connecticut

The Westinghouse Electric Corporation
95 Orange Street
Newark 1, New Jersey

Meter Jewel Inspection Service

(Check with meter manufacturers to determine policy of each)

The Eastern Specialty Company
3617 - 19 North 8th Street
Philadelphia 40, Pennsylvania

Recommended Books on Metering and Meter Testing

Electrical Metermen's Handbook, Edison Electric Institute, 420 Lexington Avenue, New York, N. Y.

Electric Power Metering, McGraw-Hill Book Company, Inc., New York, N. Y.

Practical Electric Metering, John Wiley & Sons, Inc., New York, N. Y.

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